The Role of Smart Farm Management System in Promoting Smart Agriculture in Taiwan

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ABSTRACT

In the 21st century, Taiwan is facing significant challenges such as land fragmentation, agricultural labor population decline, and unpredictable weather conditions caused by climate change which all put stress on agricultural outputs. While facing the formidable stress in production management, it becomes one of the essential tasks for government officials in Taiwan to take advantage of the well-developed Information and Communication Technologies (ICTs) to improve the development of smart agriculture and enhance the competitiveness of Taiwan's agricultural industry. In 2015, the Information Management Center (IMC) of the Council of Agriculture launched the project "Smart Farm Management System (SFMS)" (https://agrepm.coa.gov.tw/) for agricultural enterprises which aims to facilitate the recording processes on farming practices and put the smart agriculture tools in practice to improve its production. In the future, IMC will keep improving on the user-friendly interface to increase the utilization of smart farming systems locally, the tight development of the chain of government and the close management of the supply chain to implement the policy of food security and traceability. In this connection, it is very important to use the database collected from the environmental IoT network to monitor the changes in the growing environment and maintain high production and quality With long-term data collection, AI prediction models can be built to reduce the labor used, time consumed, and mitigate the impact of extreme climate. We're looking forward to the fruitful outcomes from the smart agriculture development in Taiwan which will facilitate the sustainability of the industry.

CHALLENGES IN PROMOTING SMART AGRICULTURE IN TAIWAN

Taiwan was one of the competitive countries in the field of agriculture during the mid-20th century due to the low cost of labor. This benefit was abated due to the structural change in the agricultural labor force caused by industrialization and globalization in recent decades. The area of arable lands was gradually decreased and the average farming block area remained scattered and small during the past 50 years. Labor structure met a dramatic change in three aspects: (1) The agricultural labor force decreased by 67.0% from 1971 to 2020; (2) Approximately 41% of farmers were over 65 years old in 2020, suggesting the growing problem of aging farmers as one of the important issues; and (3) The agricultural employment ratio rose from 10.2% in 1992 to 17.3% in 2020. In Taiwan, the change implied that the industry is shifting towards more task specification and specialization. It is also becoming more enterprising or business like. Moreover, climate change, especially global warming and extreme weather, has threatened agricultural production worldwide. Precipitation is also unpredictable and unstable which leads to deluges and droughts in Taiwan. The challenges in Taiwan's agricultural sector resulted from fragmented arable lands, aging farmers and shortage of the labor force alongside with unstable production due to climate change.

According to the report of the IMD World Competitiveness Yearbook in 2021, Taiwan ranked 8th out of 63 countries or areas. Promoting smart agriculture using Taiwan's advanced Information and

Communication Technologies (ICTs) to enhance the competitiveness of agricultural industries is one of the critical tasks for government officials in Taiwan.

COUNTERMEASURES IN PROMOTING SMART AGRICULTURE IN TAIWAN

Information Management Center of the Council of Agriculture (IMC, COA) started the "Intelligent Agriculture Production and Sales Add-value Program" and launched the "Smart Farm Management System (SFMS)" (https://agrepm.coa.gov.tw/) project in 2015. Up to 2021, there are over 18,000 users who signed up to use the "Smart Farm Management System" to manage their lands which cover more than 110,000 hectares. The usage rate suggests the projects' success and has made intelligent agriculture real. The improvement of mobile devices helps people adopt the systems and create a reasonable profit for their own businesses. Design and add-on values from the "Agriculture Mobile Service Platform" and the "Smart Farm Management System" will be briefly introduced, and followed by an explanation on the future challenges and direction of Taiwan's agricultural sector.

The Origins of the "Smart Farm Management System"
Due to the small business scale and crops diversification in Taiwan's agriculture industry, producers faced a management dilemma. Furthermore, to fill up the experience gap of young generations, it is more important to rely on the information system to help the production decision making. In this regard, the "Smart Farm Management System" is developed to address the following issues:
(1) Land fragmentation: Because of the scattered lands and small plots, the large-scale cultivators who conduct contract farming or cluster farming with a group of smallholder farmers face challenges to control the situation of sectioned lands and ensure the completion of the required works;
(2) Inheritance of agricultural knowledge: There is a hurdle in how to pass the experience precisely from the senior farmers to the junior farmers for accelerating the adoption in the field of agricultural activity;
(3) Importance of traceability: People are more focused on the production transparency of food nowadays due to food safety issues. However, current paper recording practice not only adds extra pressure to farmers but also lacks the timeliness of real-time records and data accuracy is also poor; and
(4) Farming resource management: The utility and allocation of farming resources for multiple producers were inefficient, such as work time management, the record of agricultural machinery and materials usage.

Functions of the "Smart Farm Management System"
To resolve the aforementioned problems, the "Smart Farm Management System" is developed to provide the following functions:
(1) A convenient tool for cultivating land management: This System is connected to the cadastral database of the Council of Agriculture, featuring precise and handy managing functions for cultivating lands. One can input the land section and land number through the embedded API services to access the correct location, then get the target land's GPS location with the assistance of mobile devices and display visual graphs to show data including all cultivating locations and crop information.
(2) Practical cultivating calendar: Farmers can set up cultivating schedules from previous generations, or import operating modes suggested by agricultural research institutes with the "Crop Cultivating Calendar" to dispatch field tasks, and plan working schedules according to different crops or species. Cultivating statuses are shown on computers or mobile devices briefly to facilitate management for users.
(3) Comprehensive field record: Through mobile devices, farmers can make efficient records on the spot, taking on-site photographs of cultivating lands or field tasks statuses, to ensure the instant and variety of field tasks recording, and further achieve the goal of agricultural products' traceability and data transparency. The SFMS also provides data through embedded API services to the "Taiwan's Good Agricultural Practices (TGAP)" system, boosting its efficiency by reducing repeated maintenance of data.
(4) Agricultural tasks in a grasp: Field tasks management and tracking were made possible through utilizing computers and mobile devices, with convenient operating interfaces and intelligent management functions. Farmers can do the overall planning, dispatching, and management of

field tasks in advance, make human resource arrangements, task status tracking, and record inspections anytime, to make sure all tasks are done as scheduled.

The aim and development direction of the "Smart Farm Management System"

The "Smart Farm Management System" has two major development goals:
(1)   Simplify the production management system; and
(2)   Improve the production management efficiency, which involves:
    i.   Minimum work and inputs on information integration and data import;
    ii.   Cross-platform support system, so that users can operate on Web, iOS, or Android mobile device application, using the system whether outside or indoors, preventing huge paper works;
    iii.   Synchronization and offline access features of the mobile device application, preventing data loss when being offline; and
    iv.   High compatibility of the system, in other words, users can choose their roadmaps or functional stage according to their organizational operation procedures.

In addition, the system allows the extension of features and customer service annually, so that the technology can keep up with the times, meeting all users' needs in the future.

Main features of the "Smart Farm Management System"

(1)   Improve work efficiency and reduce labor costs
The land is one of the fundamental issues in agriculture. The first step for attracting users to the agricultural system should be to have a visualized arable map. However, the utility of agricultural management is limited to well-known tools such as Google Map which does not provide land boundary and area conversion directly. The COA referred the data from the Department of Land Administration of the Ministry of the Interior to establish a National GIS Cadastral Map System (https://gis.coa.gov.tw/land/), which provides the "Smart Farm Management System" to display the size and shape information of a given cultivated land. Therefore, diversified users such as large-scale producers, outsourced farming or spraying workers, consultants, or certification bodies can manage their land resources, and/or arrange cropping schedules on a certain land on the system. At the next step, the navigation function is added on, therefore mobile device users can plan and execute their daily tasks among plots of land effectively.

(2)   Improve utilization capabilities and carry out the increase of transaction volumes
Farmlands owned by independent owners in Taiwan are composed of scattered lands and small plots. It means that the relationships between people and lands are complicated. Larger scales are usually referred to as higher complexity in agricultural management because land ownerships are not merged along with the scale expansion. In the "Smart Farm Management System," the three-level structure of authority was designed for farm management. Managers can book and assign tasks to their organization members to a specific plot. The executors then can report and upload records on the same page. Today, the system assists at least one of the users in managing more than 1,700 plots. This amazing achievement is difficult to accomplish with traditional paper works. The improvement of management capacities supports that operation scales which can be expanded successfully.

(3)   Enhance the efficiency of farm management by establishing the cultivation calendar
The SFMS equipped with the cultivation calendar which was suggested by experts of experimental institute or could be customized by the user. According to the calendar, users can arrange the planting schedule and predict the time of harvesting. Using this function can do a better assignment to the contracted farmers and upgrade the efficiency of management between production and marketing, especially for the agricultural industry.

(4)   Give better traceability and promote agricultural sustainability based on reliable cropping records
Food safety and traceability have been the major concern of consumers in recent decades. Implementation of Taiwan's Good Agricultural Practices (TGAP) is accepted to be an ideal solution in the domestic markets. In fact, TGAP certification is also necessary for transactions of certain agricultural products in well-known supermarket stores in Taiwan or for export (to Japan as an example). Producers guaranteed that the TGAP certification must pass the audit of the certification body, and log in the production records (such as the usage of chemicals, field operations, etc.) in the official TGAP Resume System (https://resume.afa.gov.tw/). In the past,

redundant work was written down and keyed in the "diary" and took a lot of time to do so. This procedure is now simplified in the "Smart Farm Management System." The system users can export the records required for annual audits. Every operation following TGAP rules in the "Smart Farm Management System" can be uploaded to the TGAP Resume System without repeated import. The system provides an alternative choice to directly acquaint customers with producers and their products. The customized pages were well designed so that system users can demonstrate the cropping information on the Web or share it with the Taiwan Agricultural Products Production Traceability System (https://qrc.afa.gov.tw/).

(5) Reduce waste loss by early warning and standardized management
Waste is the invisible cause of revenue loss. For example, waste from cosmetic specifications, weather, pests and diseases, harvest, storage, and supply and demand contribute even 50% to vegetable production. The "Smart Farm Management System" is aimed to assist users to recognize and monitor any risks linked to mitigate the loss from wastage. This is accomplished by the early-warning mechanism and standardization of certain cropping procedures. The "Smart Farm Management System" provides weather data from 569 stations of the Central Weather Bureau. The environmental data or physiological data detected by commercial sensors can be imported into the system. Producers can set up the warning threshold of a given observation (such as temperature, relative humidity, etc.) in the system and will be notified when an abnormal event occurs. Another active early-warning notification is contributed by the "Agriculture Mobile Service Platform." When the regional warning is announced for a specific crop by the government, the "Smart Farm Management System" will alert users who have the matched crop around the region immediately. All the activities and records are powerful in the SFMS because it is not only the history of the land usage but also the knowledge of land utilization. This knowledge helps producers to standardize the cultivation plan, respond to changes in the environment or markets, and share the right actions on revenue growth.

Best practice of the "Smart Farm Management System"
The use of the "Smart Farm Management System" not only effectively promoted the management of agricultural tasks of "West Changhua County grains supply chain" but also drastically improved the accuracy of the cultivating area, the management of cultivated location, dispatch, field operation documentations and the tracking of the cultivated status of each land, and solving problems caused by outsourcing farming. For instance, cultivating area was formerly approximated orally, causing uneven distribution of financial balance. The cultivating land management service provided by the SFMS can precisely locate the cultivating lands, while documenting essential data from the land and its size, reducing common outsourcing farming complications such as unclear calculation of fees or inaccurate land location. The clarification of agricultural costs and financial balance control is hence enhanced. The area managed by outsourced farming businesses has incremented from 50 hectares to more than 100 hectares currently by introducing the "Smart Farm Management System."

FUTURE PROSPECTS

The introduction of information technology in the agricultural sector is not difficult. The real challenge of agricultural departments lies in the generalization and local implementation of the information system. Since its appearance, the "Smart Farm Management System" has accumulated more than 19,000 users, covered 130,000 hectares of cultivated lands, but still has notable rooms for improvement. There are approximately 542,000 agricultural laborers in Taiwan, including 141,000 laborers from the younger generation. Therefore, besides promoting intelligent agriculture by constantly optimizing, simplifying the operating interfaces, and helping young farmers to use them, taking into consideration the common issues faced by Taiwan's smallholders such as the competitive agricultural goods market, lack of marketing channels and poor bargaining power, the "Smart Farm Management System" emphasizes business model for contract farming management. Contract farmers can achieve rapid documentation and reporting, while managers can instantaneously be updated on production period and amount. All parties can focus on their tasks to satisfy the requirements regarding the agricultural products' quality, quantity, and meeting the supply schedule for the channel markets. This will boost the incentive for smallholders to use the system.

The promotion of the "Smart Farm Management System" will also relate to the uprising of consumer awareness, as the importance of production records is becoming more and more valued, the transparency from farm to table is also becoming a trend. With the government proactively promoting

policies regarding the traceability of agricultural products, organic and environmentally friendly farming verifications, the system emphasizes relevant functions to boost usage rate. Thanks to the SFMS, the verified area by TGAP has been increasing rapidly from 14,000 hectares to 57,000 hectares during the past 5 years resulting from combining the functions of convenient recoding and automatic interfacing between TGAP in SFMS. The outlook for SFMS in promoting smart agriculture is promising.

 Besides, with the development of technology and the internet, the "Smart Farm Management System" will also integrate IoT data to monitor changes in the crops' growing environment and send out alerts so that farmers can take immediate actions proactively providing more satisfactory growing environment for crops, to maintain its quantity and quality. The massive amount of accumulated data also plays an important role in AI prediction modeling. Apart from reducing time and financial costs, this can further minimize the impact of extreme climate. We look forward to the constant improvement and localization of intelligent agriculture, to help keep Taiwan's agriculture become more sustainable for generations to come.

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ACKNOWLEDGMENT

AUTHOR'S CONTRIBUTIONS

The promotion of SFMS were made significant progress through the lead of the author. The author had also contributed in part to policies and the development of the technologies presented in the paper.

DECLARATIONS

The author declares that she has no competing interests in the completion of this paper.